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Abstract

The aim of this article is to introduce for the first time the topic of 'stranded assets' into research involving the built environment. It focuses on the idea that climate change policy could induce the stranding of some conventional property assets in the global real estate market. Principally, the empirical focus for study is the UK interaction with energy performance certificates and minimum energy performance standards. However, comparisons are made internationally, and key distinctions are made between developed and less developed countries. The article observes that stranded assets are not new in real estate; the changing consumer demand of occupiers has regularly rendered property assets redundant or obsolete. However, what is new is the influence of climate change and associated environmental policy on some property assets. The article deliberately combines conceptual agendas often studied in isolation. Theories of path dependence and lock-in are used to understand the problematic traction of climate change legislation within traditional real estate institutions. The implications of this situation, the potentially hidden systemic socio-economic reach of stranded assets, is then considered through the lens of contemporary debates of financialisation. Socio-technical system theory, as it relates to contemporary energy policy regimes, is then examined to connect persistent lock-in with financialised global investment markets. The article then posits how associated legislation could be used to capture a global picture of stranded assets in real estate. Revealing the stranded asset exposure should be a concern to real estate investors and those charged with managing such assets. However, more optimistically this potential risk may provide the catalyst for energy efficient transition in the built environment. The article concludes by outlining an interdisciplinary research agenda for stranded assets in global real estate.

Keywords	Stranded assets; real estate; environmental policy; urban evolution
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31 28 charged with managing such assets. However, more optimistically this
32 29 potential risk may provide the catalyst for energy efficient transition in
33 30 the built environment. The article concludes by outlining an
34 31 interdisciplinary research agenda for stranded assets in global real estate.

40 32 **Key words:** Stranded assets, real estate, environmental policy, path
41 33 dependence, financialisation, socio-technical systems, climate change.

46
47 34 **1. Introduction**

48
49 35 Stranded assets are assets that have, 'suffered from premature or
50 36 unanticipated write-downs, devaluations or conversions to liabilities'
51 37 [Caldecott, 2016]. The scope of this article focuses on the issue of climate-
52 38 related risk and opportunity, primarily the under researched idea that
53 39 climate change policy, as it relates to energy transitions, could induce the
54 40 stranding of some conventional real estate assets in the global real estate
55 41 market. The underlying research question considers,

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58 42 *To what extent is the global real estate market exposed to the energy*
59 43 *policy related stranded asset threat?*

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61 44 Upon answering the underlying research question, the primary aim of the
62 45 article is to introduce the topic of climate-related 'stranded assets'
63 46 [Caldecott, 2017] into the heterogeneous global real estate asset class for
64 47 the first time. Necessarily, the article is broad in nature, providing a
65 48 commentary on stranded assets in the global real estate market, with the
66 49 intention of acting as a staging post for a new research agenda into how
68 50 environmental related risk might transpire and strand real estate assets.

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70 51 The main sections set out a new conceptual agenda that, firstly, reveals
71 52 and then, secondly, seeks to understand stranded assets in global real
72 53 estate markets. It originally combines theories of path dependence,
73 54 financialisation and socio-technical systems with energy performance
74 55 labelling to reveal the nature, magnitude and reach of stranded assets in
75 56 global real estate for the first time. The article then reflects on these
76 57 findings to set out an international research agenda for stranded assets
78 58 in global real estate research. This research agenda expands upon the
79 59 initial conceptual process outlined in this article and posits some research
80 60 opportunities relating to climate-related stranded assets. This section
81 61 moves beyond the mostly Western European and North American
82 62 perspectives in the main body to consider how a global research agenda
83 63 could be meaningfully tackled with alternative methodologies and
84 64 conceptual perspectives. The article then concludes by reflecting back on

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92 65 the underlying research question and considers some limitations to the
93 66 research.

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95 67 The motivation for this research is to provide a sound basis for policy
96 68 makers when governments and practice evaluate ideas for climate
97 69 change transition and adaptation in the real estate sector. For those
98 70 property professionals involved in the day-to-day management of real
99 71 estate assets in the developed world, the article provides an approach to
100 72 understanding the wider significance of climate-related threats, which
101 73 we hope, will contribute to more knowledgeable and effective practice in
102 74 relation to real estate-based stranded assets. Expanding knowledge in
103 75 this area will help city leaders, investment portfolio and asset managers
104 76 in mature urban areas deal with the challenges of adapting an ageing
105 77 property stock.

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108 78 However, it is also hoped that this approach will help city leaders and
109 79 property professionals dealing with the demands of accelerating
110 80 urbanisation in the less developed world, which requires an
111 81 understanding of urban development processes and the potential impact
112 82 of stranded assets. Encouragingly, less developed countries may have the
113 83 potential opportunity to leapfrog climate-related stranded asset risk in
114 84 real estate. This is because their built environments are often relatively
115 85 younger. The fifth section argues that these locations may be able to
116 86 bypass intermediary stages of urban development, avoiding the costs of
117 87 adaptation, and potentially becoming leaders in sustainable property
118 88 through new urbanisation and smart city development. However, in line
119 89 with the arguments of Perkins (2003), the article cautions against overly
120 90 optimistic interpretations of leapfrogging that ignore the context of such
121 91 locations in relation to project goals, technology and institutional
122 92 capacity when outlining a research agenda for stranded assets in global
123 93 real estate.

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128 94 Conceptually, the article also aims to demonstrate how the afore
129 95 mentioned theoretical agendas, predominantly found in social science
130 96 and often studied in isolation and/or in discreet locations, can be
131 97 combined to shed new light on the traditional econometric and technical

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137 98 perspectives found in global real estate studies and practice based
138 99 investment methodologies in a novel way.
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140100 **2. Theoretical perspective**

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142101 In order to answer the research question, and in part response to the call
143102 of Eames et al, (2017) for more cross-transfer of learning and multi-
144103 disciplinary research in sustainability transitions, the article links research
145104 in energy policy and built environment retrofit to introduce the stranded
146105 asset issue. It then strategically combines conceptual agendas seen in the
147106 respective path dependence, financialisation and socio-technical system
148107 fields to reflect upon this situation.

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151108 The article situates the emerging stranded assets literature with theories
152109 of path dependence and lock-in developed in economic geography to
153110 understand the impact of climate change legislation within traditional
154111 real estate institutions and the persistent silence of stranded assets.
155112 During the early 1990s path dependence was introduced as a new
156113 alternative to the orthodox neo-classical economic perspective based on
157114 optimisation and equilibrium (Henning et al, 2013). Concurrently, it also
159115 took route in the history of technology field. Arthur (1989) separated the
160116 economics discipline into 'conventional' economics that did not recognise
161117 historical contingency and 'contemporary' economics which embraced
162118 path dependence and evolution (Henning et al, 2013).

164119 The latter perspective emphasises that decisions are not only influenced
165120 by present conditions but also include decisions that have been taken
166121 previously. These interpretations are now widely used within the retrofit
167122 and energy transition literature (see Dixon et al 2018) to understand how
169123 socio-technical systems and regimes endure and are potentially
170124 disrupted. This article uses Grabbers (2003) treatment of the issue to
171125 understand how political, functional and cognitive forms of lock in
172126 coalesce to strand assets in real estate practice.

174127 The article then reflects on the systemic socio-economic reach of
175128 stranded assets through the lens of contemporary theories of
177129 financialisation developed in urban studies. Fields (2018:119) recently

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182130 defined financialisation as ‘an idea that has taken hold as a means of
183131 understanding the distinctive role of finance in contemporary capitalism,
184132 and its influence on space, the economy, governance and everyday life.’
185133 In recent decades, the financialisation literature has emerged as a
186134 powerful medium for understanding how assets are securitised and then
187135 invested through international capital markets. For example, Weber
188136 (2015) has investigated the Tax Increment Finance agenda in North
189137 America, Aalbers (2012) has investigated the international mortgage
190138 securitisation market and the sub-prime mortgage fallout, while Gotham
191139 (2017) has considered disaster relief funding. More recently, Fields (2018)
192140 and Beswick and Penny (2018) have examined housing finance and local
193141 asset backed vehicles, while Christophers (2019) has started to think
194142 about how institutional investors think about fossil fuel risk. However, as
195143 Fields (2018) argues, the process of financialisation is often poorly
196144 understood and utilised as an explanation in itself without any
197145 investigation into how the process of financialisation occurs
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201146 In response to this criticism of financialisation, the article then moves on
202147 to examine contemporary energy policy and how associated socio-
203148 technical legislation could be used to capture a global picture of stranded
204149 assets in real estate, connecting the persistent behaviour of practice that
205150 ignores stranding into the global capital markets that are implicit in
206151 financialisation. This examination responds to the earlier critique of Fields
207152 (2018) but also by investigating energy performance certificates and
208153 associated legislation, that of Latour (1999) in to ‘black boxing’ technical
209154 artefacts that, due to their success, are often ignored by social science
210155 research (Swan, 2013).
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214156 Drawing on the work of [De Greene , 1973], [Eames et al, 2013] and
215157 [Dixon et al, 2018], energy performance labelling is considered an
216158 example of a potentially global integrative socio-technical regime or
217159 system connecting society’s complex technical procedures (building
218160 design) with human behaviour (building use). In this article, a socio
219161 technical regime is considered ‘a shared set of rules and routines
220162 embedded in socio-technical systems to ensure that they can provide the
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relevant social function' (Schot et al, 2016:16061). While the closely related socio-technical system rests upon the, 'premise that social and technical systems are co-constituted and co-evolve across time and space' (Lowe et al, 2017:5). Geels (2005:5) suggests that socio-technical systems display the following characteristics in society, 'technology, regulation, user practices and markets, cultural meaning, infrastructure, maintenance networks and producing systems.' In this sense, it is also important to note that real estate markets, the process of financialisation and global investment markers can also be considered socio-technical systems themselves within a complex adaptive system.

The energy labelling system functions as a method for understanding society's energy use, and through consequent minimum energy performance legislation, how such use can be monitored and improved. However, the same regime system has the potential to hardwire and connect valuation risk into global capital markets. In this sense, EPCs and associated minimum energy rules prime already financialised real estate assets (for example through international mortgage markets, Real Estate Investment Trusts, Unit Trusts and Property Companies) for stranding. EPCs, in this sense, play the dual role of conceptually connecting lock-in with financialisation but also, empirically, the potential role of capturing the magnitude of the stranding issue in global real estate. Therefore, the nature of the research is part conceptual, in setting out a framework for understanding stranded assets and part empirical in using energy performance certificates to capture the size of the stranded assets threat.

In this paper, real estate is taken to mean, broadly, all residential, commercial, and operational property. This is a broad characterisation that is used to help reveal the stranding problem in global real estate. The authors concede that this definition simplifies the inherent variability found within respective real estate assets and return to this issue at the end of the article in suggesting opportunities for further research. Principally, the focus for study is the UK; however, comparisons are made internationally, and key distinctions are made between developed and less developed countries.

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The authors note that the traditional binary distinction between developed and less developing countries is problematic, certainly over simplifying the rich diversity of characteristics found within and between each relative classification. Indeed, the World Bank dropped the categories ‘developed’ and ‘developing’ from its economic vocabulary in 2016. Instead, the authors use the broad distinction of ‘developed’ and ‘less developed’ to compare the relative maturity of built environments in such locations, rather than making any assumptions about the respective locations economic or social capacity. The authors then revisit this distinction at the end of the paper suggesting alternative measurements and perspectives as a rich opportunity for further study.

3. Climate change and nature of real estate markets

The article observes that stranded assets are not new in real estate, as the changing consumer demand of occupiers has regularly rendered property assets redundant or obsolete - exhibiting the creative destruction outlined by Joseph Schumpeter in 1950. However, what is new is the influence, systemic reach and disruption of climate change and associated environmental policy on some property assets, related capital markets (at the macro scale) and individual communities (at the micro scale) that are reliant on homes to live, and commercial property to work.

At the same time as the global emphasis on sustainability, the international real estate sector is going through its own set of structural growing pains in response to dynamic changes in residential and business practices - potentially coalescing with and exacerbating the climate-related stranded asset issue. For example, the appetite for smaller commercial floorplans in the office sector, the impact of the internet on the retail sector, and the disruptive influence of new property technology on conventional real estate living and working conditions have all increased uncertainty in the global real estate market.

In response to climate-based threats and associated environment policy, there is now pre-emptive need for new arrangements of land, unconventional forms of buildings, and creative adaptations to the

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317 228 existing property stock to combat the threat of devaluation [Wilkinson et
318 229 al, 2107], [Eames et al, 2017]. However, at the same time, there are
319 230 several opposing forces that make pre-emptive action involving energy-
320 231 efficient retrofit measures (or new sustainable construction) difficult in
321 232 the developed world. Grabher's [1993] treatment of path dependence
322 233 and 'lock-in' is a suitable analytical framework to understand this
323 234 situation. Setting aside the sheer cost involved in adapting real estate
324 235 assets in the face of climate change [Eames et al, 2017], path dependence
325 236 and lock-in is concerned with the persistent behaviour of people, society,
326 237 business, and locations as they maintain and reinforce historical
327 238 behaviour in contexts that are significantly different to the original
328 239 historical circumstances [Henning, 2013]. Grabher [1993], researching in
329 240 the field of regional economics, describes three interrelated types of
330 241 'lock-in': political, functional, and cognitive lock-in. These same
331 242 constructs can also be used to help explain the existence and silence of
332 243 stranded assets in global real estate debate and practice and some of the
333 244 drags upon retrofit in the built environment.

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338 245 Political lock-in explains circumstances in which traditional courses of
339 246 development are retained and reinforced by pre-existing stakeholders
340 247 and institutions, inhibiting adjustment to new considerations and policy
341 248 directives. Bishop and Williams[2012] and Henneberry [2017:1-2]
342 249 illustrate this situation when they argue that cities in the developed world
343 250 have gradually become more 'formalised and permanent'. Proliferating
344 251 layers and intensities of legislation '(some with a long history but most
345 252 introduced in the 20th Century) covering building construction, fire
346 253 prevention, public health, building conservation and land use planning
347 254 have solidified the urban built environment'. This echoes the recent work
348 255 of [Dixon et al, 2018], who see individual cities, as a complex mix of
349 256 homes and businesses, and the product of many hundreds of years of
350 257 evolution and growth that become locked into patterns of resource use
351 258 that can no longer be justified. This intransigent situation makes it more
352 259 difficult for the existing built environment to change. This is subsequently
353 260 later compounded by the slow replacement of real estate stock (IRENA,
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362261 2017) which typically only accounts for 1-3% of stock per year (Zhenjun
363262 et al, 2012; Eames et al, 2013;Itani et al, 2013).
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365263 Cognitive lock-in relates to collective ideas and beliefs that inhibit the
366264 acceptance of new ideas - overlaying physical rigidity in the built
367265 environment is a climate of institutional inertia. Muldavin [2010] argues
368266 that although important steps have been taken, the real estate sector is
369267 struggling to confirm the value of sustainability in property investment.
370268 Although there have been amendments made to the RICS Red Book
372269 [2013], alongside a Guidance note on Sustainability and Commercial
373270 Property Valuation [2014], it has been difficult for the traditionally
374271 sluggish real estate sector to take on board sustainability objectives.
375272 Primarily, this is because there has been no demonstrable enhancement
376273 to return [Dixon, 2014]. This is because the imperfect implications of
378274 stranded assets - implicit in sustainable development - are very awkward
379275 for mainstream real estate research to digest. Traditional paradigms in
380276 real estate economics and related practice, for example the valuation of
381277 property, and modern portfolio theory are anchored in the maximising
382278 presumptions of the rational investor. It is not straightforward to capture
384279 the cost or potential premium afforded by sustainability, as valuation is
385280 typically backward looking based upon retrospective property valuation
386281 [Diaz and Hansz, 2001]), resulting in a lack of scrutiny by valuation
387282 professionals [Lützkendorf and Lorenz, 2005], [Lorenz and Lützkendorf,
388283 2011], [Michli et al, 2016]. Similarly, real estate investors make decisions
390284 and monitor progress against historical performance benchmarks and
391285 indices, such as those provided by the Investment Property Databank
392286 (IPD) and CB Richard Ellis.

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394287 Functional lock-in, in this case, relates to the too-close connection
395288 between historical building functions and worth, which inhibits
396289 consideration of external change. Illustrating this situation in the real
397290 estate sector, the common treatment has been to situate the analysis of
398291 stranded assets in the depreciation and obsolescence literature. There is
400292 a variety of informative applied depreciation studies by [Baum, 1991],
401293 [Baum and McElhinney, 1997], [Dixon et al, 1999] [Dunse and Jones,

2002], [Andrew and Pitt, 2006], [Crosby and Devaney, 2006], [Mansfield, 2009], and [Crosby et al, 2011]. However, broadly speaking, in this perspective functional real estate assets grow old, become less productive, and must then be improved or replaced. Through this process, loss of value occurs gradually in a typically linear fashion related to the original function of the building rather than under external conditions of sudden market disruption [Christensen, 1997].

On one hand, the potential stranded asset threat, initially associated with value of unburnable carbon stocks [Krause, 1990], [Carbon Tracker Initiative, 2013] and more recently following the Paris Agreement [Covington, 2013], has the potential to blow this market lethargy wide open. This is because, until now, sustainability has mostly been seen as an altruistic choice or government concern associated with environmental objectives rather than business necessity. On the other hand, traditional real estate valuation methods are still based on the most recent comparable transaction advice rather than any forecast of sustainability value or fossil fuel liability, resulting in a stranded asset knowledge deficit. Illustrating the consequences of this situation, [Warren-Myers, 2012] argues that without confirmation of environmental value, sustainable investment (or fossil fuel disinvestment) will be constrained in the real estate sector. The next section, in part, aims to fill this gap in knowledge by connecting impact of path dependence and persistent behaviour into global capital markets through the process of financialisation.

4. Stranded assets and the global real estate market

The following section brings forward the path dependent traditions in real estate practice and connects this into the financialised reality of global real estate investment markets. This is in order to reveal the potential gravity of stranded assets but also to show how ingrained practices in real estate have the potential to create risk in global capital markets. In recent years, climate-related stranded assets have received international attention from the UN [McGrath, 2014], the North American government [Friedman, 2014], the OECD [Gurría, 2013], the

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452327 Inter-American Development Bank [Caldecott, 2016], the G20 Financial
453328 Stability Board, and the Bank of England [Carney, 2015]. However, the
454329 same issue has received very little attention in the real estate sector
455330 [IRENA, 2017 is a notable exception), even though the real estate sector
456331 shares and potentially intensifies many of these same risks downstream.
457332 Given that real assets make up a large part of total global investment
458332 worth and are a significant store of national, corporate, and individual
459333 wealth, the omission of real estate from the stranded assets discourse is
460334 a significant omission.
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463336 Traditionally, real estate assets share many of the same imperfect
464337 investment characteristics as fossil fuel assets in relation to liquidity,
465338 fungibility, and transmission of potential risk. For example, both assets
466338 classes are heterogeneous, typically, no two assets are the same and they
467339 take considerable initial investment to exploit, there are few buyers and
468340 sellers in the market place (due to cost and location), market entry and
469341 exit is difficult (due to ownership monopolies, the illiquid nature of assets,
470342 and government legislation), and both types of asset are typically fixed in
471343 location (either under it or built on top of it).
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474345 The respective asset classes are also interrelated. Traditionally,
475345 residential and commercial property assets have been powered by fossil
476346 fuel-dependent heating and ventilation systems. Furthermore, the urban
477347 sprawl associated with suburban residential property, out-of-town office
478348 parks, and retail centres, has evolved in tandem with the fossil fuel-based
479349 automobile. There is also a distinct and highly expensive set of
480350 operational property assets that has been constructed to directly serve
481351 the fossil fuel sector, for example, coal-fired power stations, which are
482352 typically highly leveraged (exposed to debt finance) and have no obvious
483353 alternative use [IRENA, 2017].
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487355 The global value of real estate is \$217 trillion (of this \$162 trillion dollars
488356 is residential, \$29 trillion dollars is commercial and \$26 trillion is
489357 agricultural land), roughly 2.7 times global GDP, making up roughly 60%
490358 of all mainstream investment assets [Savills, 2016]. Furthermore, the
491358 value of the new construction market will be \$17.5 trillion in 2030, an \$8
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497360 trillion increase on present-day values [Oxford Economics, 2015]. In large
498361 part, the volume of real estate assets in global investment portfolios and
499362 the circulation of the same assets in international capital markets is down
500363 to increasing levels of financialisation outlined in recent years by [Weber,
501364 2010], [Aalbers, 2017], [Christophers, 2017] and [Fields, 2018].

503365 Hitherto, stationary physical real estate assets have been increasingly
504366 repackaged into a rash of financial products and funds, including
505367 derivatives, real estate investment trusts, and debt vehicles. This process
506367 has been intensified during periods of political and fiscal uncertainty
507368 because real estate has increasingly replaced Government Bonds as a
508369 provider of fixed income in investment portfolios. This has expanded the
509370 tentacles of property asset value throughout global finance networks.
510371 The implication is that stranded real estate assets provide a vehicle for
511372 intensifying the threat of climate-related stranded assets because they
512373 reach further into and have broader exposure in capital markets than
513374 fossil fuels assets. Look no further than the 2008 global financial crash for
514375 an illustration of the sudden impact and systemic influence of real estate
515376 based financial products. Despite sustainable intervention, including
516377 enhanced insulation, better glazing, and utilising solar power and
517378 biomass, global property stock is still reliant on fossil fuel for heating and
520379 ventilation. This perspective sheds a new light on contemporary debates
521380 of financialisation that typically analyse the creation of new asset classes.
522381 This article looks at a product, global real estate, which has been
523382 financialised for many decades and considers how this previously
524383 relatively stable system is at risk of disruption.
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528385 The following section utilises the outputs of international building energy
529386 performance legislation to outline a model for understanding climate-
530387 related stranded asset exposure. The same legislation and EPC regime is
531388 also the conceptual bridge that connects path dependence into the
532389 financialised global real estate market.

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542**5. Climate-based real estate legislation**
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544 Global real estate is essential for urban development. However, it
545 expends physical resources and is the origin of considerable emissions. A
546 conservative estimate is that global real estate consumes 40% of global
547 energy annually and accounts for more than 20% of international carbon
548 emissions [World Economic Forum, 2016]. As part of international efforts
549 to reduce carbon emissions, real estate and its associated built
550 environment has been identified as a major contributor toward planetary
551 warming [IPCC, 2014]. For example, the UK government aims to reduce
552 UK real estate CO2 emissions to close to zero by 2050 to attain its energy-
553 efficiency targets. This aim has been repeated around the world and is an
554 example of an attempt at a socio-technical system transition.
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557 Consequently, in recent decades, the real estate sector has been at the
558 forefront of climate change legislation, designed to reduce its impact on
559 the global environment. Environmental labelling, endorsement based
560 and comparative [Reed et al, 2009], has been a central tool in reducing
561 the environmental impact of building stock. Typically, environmental
562 labelling has adopted either a multi-criteria sustainability approach or a
563 narrower focus on energy [Sayce et al, 2010]. In the 1990s, the BREAAAM1
564 tool led the way in the UK (multi-criteria), soon to be followed in France
565 by the HQE2 model (multi-criteria), the Swiss Minergie3, and the North
566 American Energy Star4 (both energy). In the 2000s, these models were
567 joined by further multi-criteria schemes, LEED5 (North America),
568 CASBEE6 (Japan), Green Globe7 (Canada), and Green Star8 (Australia).
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573 Latterly, one of the most comprehensive approaches can be seen in the
574 European Union (EU). Following the 2010 EU Energy Performance of
575 Building Directive, it is mandatory for all European properties to hold an
576 Energy Performance Certificate and monitor their heating and air
577 conditioning (all 28 Member States signed up to this directive). Energy
578 Performance Certificates (EPCs) have a significant relationship with
579 climate-related stranded assets in real estate. They are a key enabler of
580 building improvement, as they have the potential to influence decision
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587425 making in real estate transactions and provide cost-optimal
588426 recommendations for energy performance improvement [BPIE, 2014].
589427 They provide the opportunity for governments to enforce minimum
590428 energy performance standards, and they are an important information
591429 tool for building owners, occupiers, and real estate stakeholders. These
592429 latter two themes form the basis for the remainder of this section. Firstly,
593430 the potential for climate-related legislation to strand real estate assets
594431 will be considered, before, secondly, the information bi-products of
595432 energy performance labels will be assessed for their potential in
596433 measuring stranded asset exposure.
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5.1 Climate-related obsolescence

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600436 The England and Wales government has used EPCs as the basis for legally
601436 enforceable Minimum Energy Efficiency Standards (MEES), legislated
602437 through the Energy Efficiency (Private Rented Property) (England and
603438 Wales) Regulation Act 2015. These regulations have fixed a minimum
604439 standard for both domestic and non-domestic privately rented property.
605439 Commencing in April 2018, any domestic or non-domestic property that
606440 is available to let with an energy performance rating below E (those
607441 properties with F and G ratings) has been deemed illegal to let – in 2020,
608442 the same rule will apply to residential property. In England and Wales, it
609443 is estimated that 10% of residential property stock (£570bn) and 18%
610444 (£157bn) of commercial stock are under this threshold. In addition, the
611444 Government in England and Wales is also considering the merits of
612445 committing to a forward plan for MEES. This would mean that the
613446 minimum energy performance regulatory standard is increased over time
614447 in order to provide medium - to long-term certainty regarding when the
615448 progressive standards will apply and when any necessary physical
616449 improvements will need to be made [Department of Energy and Climate
617449 Change, 2014].
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623454 From 1 April 2023, these regulations will apply to all non-domestic
624455 property, not only those agreeing a new let, lease renewal if an EPC is
625456 already in place, or tenants wishing to sublet [Green Construction Board,
626456 2014], [The Non-Domestic Minimum Building Energy Performance
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Standards Working Group, 2014]. Failure to meet these new rules, for example, the illegal letting of a sub-standard property, will result in a minimum fine of £150,000. There are several potential exemptions to MEES, primarily:

- Any building improvement that would alter the character or appearance of an historical (in a conservation area) or listed building,
- Where energy efficient improvements would reduce market value by more than 5%,
- The improvements do not pay for themselves through energy cost saving within a seven-year time frame,
- If the landlord cannot get consent from planning authority or incumbent tenant,
- Temporary buildings and detached buildings under 50 sqm.

To protect against MEES avoidance techniques, all exemptions must be held on an Exemption Register. The implication is that any sub-standard building will still be publicly named and shamed and may suffer yield and value depreciation. The MEES in England and Wales indicates a potential future trajectory for international property legislation, in which governments tighten up on building emissions in order to achieve climate change targets. Using the minimum energy exposure figures in England and Wales as a proxy for international energy policy and combining them with the recent estimate of global real estate value provided by [Savills, 2016], it is possible to gauge global real estate exposure to climate-related stranded assets. If all international governments followed the same strategy, the risk value for residential real estate property assets would be \$16 trillion and \$5 trillion for global commercial assets.

However, the introduction of MEES has not been without difficulty. Potentially 70% of EPC ratings in England and Wales could be incorrect (either too low or too high) due to the inconsistent quality of assessments [Hobbs, 2013], [Hosgood, 2014] and the evolving nature of the underlying

method of calculation (the Simplified Building Energy Model – SBEM). Furthermore, the government has abandoned the flagship finance mechanism that accompanied MEEs in the residential sector, the Green Deal Finance Model, and it was never introduced for commercial property. The consequence is that the England and Wales Government has sent out a very strong policy signal in favour of building improvement but has removed the primary financial means of doing so.

5.2 Exploiting climate change legislation to create an information baseline for real estate stranded assets

The first stage in tackling climate-related stranded assets in the real estate sector must be identifying their existence. IRENA [2017] have proposed an ambitious methodology for assessing the global real estate stranding asset exposure. The method utilises estimates of existing floor space, forecasted new building space, and natural demolition rates to quantify for the first time climate-related stranded assets in building stock, the impact of delayed policy action, and the cost of retrofitting sub-standard properties in response to climate-related policy action. The method lays important foundations for studying the impact of fossil fuel-related stranded assets in the real estate sector, for the first time linking the upstream fossil fuel sector into downstream real estate assets. However, due to the lack of information transparency in the real estate sector [Fuerst et al, 2011], IRENA [2017] concede that the method rests on a number of necessary estimates and presumptions and utilises a broad econometric methodology. There is considerable scope to build on this method with more detailed data sets, information resources and conceptual enquiry found in the social sciences.

The granularity and scope of the IRENA model could be significantly enhanced by using already-existing energy labelling information. For example, the mandatory EPC information held in the EU Building Stock Observatory and English and Wales EPC registry could be used to provide accurate accounts of energy use, floor space, building retrofit advice (and cost), type of property, and location. This could then be augmented with more information from the Building Performance Data Base in North

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722522 America and the National Australian Built Environment Rating System. In
723523 principle energy performance labelling provides an opportunity to
724524 accurately measure climate-related stranded asset exposure in the
725525 developed world. However, information is less readily available in the less
726526 developed world. Those areas of the world with less transparent
728527 property markets, for example China (the Three Star Rating Building
729528 System) and South America (for example the RTQ-C and RTQ-R
730529 methodologies in Brazil), are increasingly adopting building energy
731530 performance standards, which reveal the opportunity for comprehensive
732531 international energy performance data bases in the future.
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734532 Information generated from mandatory EPC assessments could be taken
735533 further. Issues of consistency and accuracy (a problem shared with the
736533 wider real estate market) significantly hamper meaningful assessment of
737534 stranded assets and energy performance in real estate stock.
738535 Increasingly, contemporary real estate data sets include Unique Property
739536 Reference Numbers (UPRN). UPRNs enable the linking of disparate data
740537 sets to provide more powerful, multi-criteria data sets and provide a
741538 consistent identifier throughout the building life cycle – from initial
742539 planning consent to final demolition. However, EPCs do not carry a
744540 requirement for a UPRN; this is a missed opportunity. For example, in
745541 England and Wales, the presence of a consistent UPRN would enable the
746542 linking of EPC information to National Valuation data sets. Each property
747543 in England and Wales is valued every five years for taxation purposes;
748544 linking both data sets would facilitate accurate measurement of energy
749545 use, floor space, and value and would assist, in part, the measurement of
751546 real estate-related stranded assets exposure to government revenues.
752547 Most developed countries typically derive some of their taxation from
753548 property, indicating the international potential for this coupling. This
754549 would potentially lead to a socio-technical energy performance baseline,
755550 which could be used to benchmark and monitor the risk of climate-
757551 related stranded assets and more generally the value of sustainability – it
758552 could also be used to potentially police transition through taxation. This
759553 would be an important innovation, as it would increase the overall quality
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767555 of property valuation by integrating carbon into statutory methods of
768556 property valuation.
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770557 **6. Developing a stranded asset research agenda in global real estate**

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772558 The first challenge for global real estate stakeholders, their professional
773559 bodies and academics is in connection to the recognition of climate-
774560 related stranded assets. This, in part, involves creating the informational
775561 baselines that reflect the existence and cost of stranding – a methodology
776562 has been outlined in this article. It also necessitates going beyond
777563 technical and atheoretical concepts of building energy to consider how
778564 EPCs and associated legislation can be an important conceptual device
780565 for connecting disparate academic agendas. An initial informational
781566 baseline only provides a broad measurement of climate-related stranded
782567 asset exposure in parts of the global real estate market. Research into
783568 stranded assets in the global real estate markets demands an
784569 international perspective and potentially a different set of methodologies
786570 and research techniques.
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788571 This article has strategically blended theories of path dependence,
789572 financialisation and socio technical systems in order to understand and
790573 reveal the stranded asset issue in global real estate. These theories are
791574 traditionally studied in isolation. However, this tactic has been necessary
792575 to reveal the global issue that may not have been possible through
793576 prescribed single case study, econometric or technical research. The
794577 authors argue that further blending of multi-disciplinary conceptual
795578 domains will be necessary to understand the variable contexts of
797579 stranded assets.
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799580 In particular, these new perspectives should be cognisant of the very
800581 different and often variable contexts in the developed and less developed
801582 world. Real estate, as it relates to energy use, in the less developed world,
802583 particularly in rural locations, is diverse – influenced by variation in
803584 population size, economic activity, resource levels, and energy profile.
804585 Due to the rapid nature of development in these locations, there is also a
805586 congested policy landscape, which makes focusing on climate-related
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812587 stranded assets problematic. Not least, the thorny subject of whether
813588 such locations should face the same stringent climate standards as the
814589 developed world when they have not had the opportunity to exploit the
815590 economic growth associated with fossil fuel use. In contrast, physical real
816591 estate development and supporting professional practice is well
817592 established in the developed world, anchored in rigid functionality and
818593 institutions – due to the age of the built environment.
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821594 Such regions can have key geographical features, which aid fossil fuel
822595 divestment in real estate. For example, generous space and excellent
823596 access to sunlight has the potential to aid the exploitation of wind and
824597 solar energy (in contrast, energy use retrofitting in the western world is
825598 exacerbated by less proximity to natural resources). This resource
826599 landscape is particularly advantageous in those locations – for example
828600 rural India – where it is difficult or unduly expensive to develop fossil fuel
829601 infrastructure or to interface with a national energy grid. This awkward
830602 situation is primarily related to the sheer logistical challenges associated
831603 with expansive and unforgiving locations and/or the paucity of capital
832604 finance.
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835605 The stranded asset situation in the less developed world also needs to be
836606 understood in the context of vastly differing circumstances. For every
837607 exemplar self-contained smart city, for example Masdar City (in the
838608 United Arab Emirates) or the Songdo International Business District (in
839609 South Korea) – exhibiting high-tech digital infrastructure, carbon-neutral
840610 buildings, green urban planning, and abundant capital finance – there are
841611 many more largely rural locations, for example Xinjiang Province in China
842612 and Bihar State in India, exhibiting marginal and fragmented locational
844613 attributes. They are quite literally operating off the conventional energy
845614 grid and outside conventional fossil fuel infrastructure routes. In these
846615 locations rather than overarching conceptual and empirical methods,
847616 such as those deployed in this article, more situationally specific enquiry
848617 may be suitable, for example case study and ethnographic enquiry.
850618 Concurrently, it is not a given that smart city developments are
851619 necessarily also clean in the energy sense. Consideration should be given
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857620 to whether developments of this nature compliment energy directives
858621 and sustainability requirements.

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860622 However, all these locations, broadly, are united by rapidly increasing
861623 levels of population and concurrent energy demand, which has put these
862624 locations on a rapid energy provision trajectory. Understanding this
863625 trajectory provides a potential opportunity to minimise climate-related
864626 stranded assets through leapfrogging before they happen whilst
865627 achieving the decarbonisation agenda [IRENA, 2017]. This is possible
866627 because large amounts of the built environment in less developing
867628 locations has not been constructed yet. However, this research needs to
868629 be approached critically, recognising that leap frogging is not a given and
869630 is contingent upon the technology available for investment; relative skills
870631 and institutional capacity; and, most importantly, political stability and
871632 will (Perkins, 2003). Indeed, Perkins (2003:) argues, “national
872632 governments will need to challenge entrenched domestic and foreign
873633 interests whose preferences lie, to a greater or lesser extent, along a
874634 business as usual path”.

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878637 To support this more critical approach, the authors suggest additional
879638 engagement with conceptual domains that interrogate emerging
880638 governance profiles in such locations; that seek to understand relative
881639 and emerging skill and institutional capacities, for example as they relate
882640 to creating an energy performance regulatory framework. This would be
883641 complemented by research that moves beyond simple binaries of
884642 developed and less developed counties in order to utilise more precise
885643 alternative measures such as the United Nations Human Development
886644 Index and that acknowledge the socially produced uniqueness of distinct
887644 real estate markets (Guy and Henneberry, 2000). This multidisciplinary
888645 approach to researching stranded assets in real estate will help
889646 investigate the following key questions in relation to mitigating and
890647 reversing stranded assets.

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894650 The global real estate sector is hugely disparate – how might climate-
895651 related stranded assets be more or less important for different types of
896651 societies, geographies and heterogeneous property assets. This article

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902 653 has broadly discussed global real estate, merging residential and
903 654 commercial property into one bulk class. In reality, these two asset
904 655 classes are completely different and should be considered as two
905 656 separate areas for study. Small individual investors with relatively small
906 657 financial stakes - many of which have the potential to avoid the legislative
907 658 radar, dominate the residential real estate sector. How will the costs of
908 659 retrofit, and the likely increase in rent, be balanced against a concurrent
909 660 demand for low cost housing demand. In contrast, commercial real estate
910 661 is typically owned by companies, conglomerates and investment bodies
911 662 who have a much larger financial stake and corporate social
912 663 responsibility.

913 664 This critical approach also has the potential to help uncover the
914 665 relationship between the normal refurbishment cycle of property and the
915 666 problem of stranding. Although the building replacement cycle is
916 667 notoriously sluggish, the occupation of buildings, particularly in the
917 668 commercial sector, is increasingly dynamic and short-lived. Could the
918 669 new era of short leases and increased opportunity for landlord/tenant
919 670 negotiation at lease renewal help ameliorate the problem of climate-
920 671 related stranding?

921 672 The approach will also help examine what the evolution of urban
922 673 locations tell us about the trajectory and potential amelioration of
923 674 stranded assets. New understanding in this area could help inform
924 675 intervention and so-called leapfrog development in the less developed
925 676 world before fossil fuel dependency is ingrained. Moreover, it can help
926 677 uncover which countries are pursuing minimum energy measures in the
927 678 developed world. For example, how many of the 28 European Union
928 679 Member States have laid down legislation to achieve this aim. This
929 680 research agenda could also help inform how considerations of
930 681 sustainability, in particular it's pricing, could be aligned with the problem
931 682 of stranded assets. Part of this must involve understanding which parties
932 683 will be paying for the retrofit challenge and where they will get the
933 684 funding from. Nothing will happen with stranded assets unless the money
934 685 is available to do the retrofit improvements. Outlining the cost risk of

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947686 stranded assets in this paper, helps justify this expenditure. Finally, this
948687 new research could help consider, what other factors (besides
949688 environmental legislation) cause stranding in global real estate markets.
950689 For example, do certain types of property, markets, and locations have
951690 systemic risk because of their underlying characteristics.

953691 **7. Conclusion**

955692 In response to the underlying research question,

957693 *To what extent is the global real estate market exposed to the stranded*
958694 *asset threat?*
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960695 The article has combined conceptual agendas in path dependence theory,
961696 financialisation research and socio-technical system studies to reveal a
962697 potential risk value for residential real estate property assets of \$16
963698 trillion and \$5 trillion for global commercial assets. The relatively novel
964699 engagement with the path dependence and lock in literature proves that
965700 history and ‘how we got where we are’ is important in understanding
966701 global real estate markets, built environments and related institutions.
967702 Indeed, our research suggests that traditional ways of working are locked
968703 into regressive valuation methodologies and that this, in part, accounts
969704 for the silence afforded to stranded assets in real estate practice. Socio-
970705 technical system theory has then been used to show how Energy
971706 Performance Certificates and associated Minimum Energy regulation,
972707 have the potential to hardwire and connect valuation risk into global
973708 capital markets. Concurrently, the informational bi-products of Energy
974709 Performance Certificates have been used to reveal the potential
975710 magnitude of stranded assets.

979711 The utilisation of financialisation as an overarching catalysing concept in
980712 global capital markets has then helped connect the property practices
981713 and techniques in the global real estate market. This research has
982714 revealed a new global asset risk in parts of global real estate that have
983715 been financialised for many decades. This presents a new emphasis for
984716 financialisation research. Contemporary research typically focuses on
985717 newly financialised assets. For example, Weber (2015) and Fields (2018)

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992718 have revealed new asset classes recently – primarily related to Tax
993719 Increment Finance and Single Family Rental assets. This research reveals
994720 what may happen to newly financialised products further down the line
995721 following disruption and reconfiguration.
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997722 The article argues that exposing the stranded asset threat could play a
998723 positive role in provoking the disruptive sustainable urban retrofit
999724 proposed by Dixon et al (2018). Connecting the “what is needed with the
1000725 how it can be implemented” at the global level. Attitudes could change
1001726 very quickly following the 2018 minimum energy performance legislation
1002727 in England and Wales (and similar minimum energy performance
1003728 initiatives elsewhere in the world). It can be speculated that rapid
1004729 devaluation in certain property assets could ensue if the legislation is
1005730 robustly enforced. If revaluation is significant in size and speed this could
1006731 affect values and behaviour in other international markets, in particular,
1007732 those areas with similar property stock characteristics in terms of vintage,
1008733 heating, ventilation and air-conditioning, and construction type.
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1012734 Adapting theories of lock in and then echoing the recent arguments of
1013735 [Silver, 2016], there are two not necessarily mutually exclusive
1014736 explanations for the silence of climate-related stranded assets in global
1015737 real estate markets. First is that the real estate market has digested the
1016738 stranded asset threat and decided that environmental legislation will be
1017739 sufficiently diluted that climate-related stranding will not impact global
1018740 real estate assets. In other words, real estate stakeholders believe that
1019741 the lobbying power of private and public capital held in global real estate
1020742 and the force of the fossil fuel sector will win out against the climate
1021743 change consensus. Under this position, significant policy related change
1022744 ‘just won’t happen’. Indications in the early part of 2019, the time of
1023745 writing, indicate that this maybe the case with little early enforcement of
1024746 the minimum energy rules. Second, the institutions and traditional ‘ways
1025747 of working’ in the real estate market are largely blind to the stranded
1026748 asset threat, locked in to traditional ways of working – they simply do not
1027749 account for it.
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Both positions are untenable, as they leave real estate assets, and the investors and communities they serve, prone to an uncertain future. Adopting the principles of Pascal's Wager, it is rational to plan for potent climate-related policy enforcement. Adapting existing buildings and constructing new developments that are not reliant on fossil fuels, although potentially costlier in the short term, can create a more resilient (and therefore valuable) asset. Ignoring climate change exposes physical real estate assets to the risk of permanent disruption as clean technology becomes more affordable, as social norms and consumer behaviour increasingly accept principles of environmental sustainability, and as investment managers and financiers increasingly demand that companies disclose business model exposure to climate change.

However, in order to begin to understand climate-related stranded assets in global real estate, it is necessary to qualify the research in this article. The wide urban context of the international perspective reveals the need for some cautionary words in relation to the context and content of the findings and conclusions in this article. The empirical approach has necessarily been one of broad review rather than detailed analysis. Moreover, our definition of real estate in this article is simplifying in its approximation - consequently, we must be careful of over-generalisation and simplification. Each international property market contains a variety of comparable but highly specific contexts, which are contingent and socially produced in each case. Furthermore, there are multitudes of factors involved in real estate obsolescence; only one of these is the climate-related stranded assets. Energy policy is only one part of a complex web of actors, interests, and relations, particularly developers but also investors, occupiers, and members of the community who are either directly or indirectly involved in the production and reproduction of global real estate assets. A great deal more research will be needed to fully understand the specific and variegated nature of climate-related stranded assets in the international context.

Yet despite these caveats, we consider that the material within provides a perspective through which a picture of climate-related stranded assets

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1083 in global real estate begins to emerge. In the energy sector, the aim of
1084 legislation is to reduce fossil fuel consumption by leaving existing assets
1085 in the ground and halting the development of new ones. However, the
1086 impact of energy policy on global real estate assets is different. The aim
1087 of legislation is to improve the quality of property and reduce its negative
1088 impact upon the environment. The implication is that those existing
1089 properties reliant on fossil fuels will need to be improved in order to meet
1090 the needs of continued urbanisation – such properties cannot just be
1091 written off as a loss as they would be in the fossil fuel sector. Illustrating
1092 the magnitude of this retrofit challenge, at the turn of the millennium,
1093 [Kincaid, 2002], referring to the UK, argued that the vast majority of 2050
1094 property stock had already been built (some of it centuries ago in mature
1095 urban locations). Reinforcing this argument, [Kelly, 2008] indicates that
1096 87% of current stock will still be standing in 2050. In other words,
1097 developed nations must go back to the future to solve the climate-related
1098 stranded asset problem through adaptation and retrofit. Conversely, less
1099 developed nations may have the opportunity to skip real estate asset
1100 fossil fuel dependency in order to define their own future.

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1 BREEAM (Building Research Establishment Environmental Assessment Method), first published by the Building Research Establishment (BRE) in 1990, is the world's longest-established method of assessing, rating, and certifying the sustainability of buildings.

2 The Haute Qualité Environnementale or HQE (high-quality environmental standard) is a standard for green building in France, based on the principles of sustainable development.

3 Minergie is a registered quality label for new and refurbished low-energy-consumption buildings. This label is mutually supported by the Swiss Confederation, the Swiss Cantons, and the Principality of Liechtenstein along with Trade and Industry.

4 Energy Star (trademarked ENERGY STAR), originating in North America, is an international standard for energy-efficient consumer products that can be applied to residential and commercial properties.

5 Leadership in Energy and Environmental Design (LEED) is one of the most popular green building certification programs used worldwide. Developed by the non-profit U.S. Green Building Council (USGBC), it includes a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighbourhoods.

6 Comprehensive Assessment System for Built Environment Efficiency (CASBEE) is a method for evaluating and rating the environmental performance of buildings and the built environment.

7 Green Globes is an online green building rating and certification tool that is used primarily in Canada and the United States. Green Globes was developed by ECD Energy and Environment Canada, an arms-length division of JLL. Green Globes is licensed for use by BOMA Canada

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1443 (Existing Buildings) and the Green Building Initiative in the United States
1444 (New and Existing Buildings).
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1446 **8** Green Star is a voluntary sustainability rating system for buildings in
1447 Australia. The Green Star rating system assesses the sustainability of
1448 projects at all stages of the built-environment life cycle. Ratings can be
1449 achieved at the planning phase for communities, during the design,
1450 construction, or fit-out phase of buildings, or during the ongoing
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Suspect foundations: Developing an understanding of climate-related stranded assets in the global real estate sector

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Paul Greenhalgh

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2 1 **Suspect foundations: Developing an understanding of climate-related**
3 2 **stranded assets in the global real estate sector**

4
5 3 **Abstract**

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7 4 The aim of this article is to introduce for the first time the topic of
8 5 'stranded assets' into research involving the built environment. It focuses
9 6 on the idea that climate change policy could induce the stranding of some
10 7 conventional property assets in the global real estate market. Principally,
11 8 the empirical focus for study is the UK interaction with energy
12 9 performance certificates and minimum energy performance standards.
13 10 However, comparisons are made internationally, and key distinctions are
14 11 made between developed and less developed countries. The article
15 12 observes that stranded assets are not new in real estate; the changing
16 13 consumer demand of occupiers has regularly rendered property assets
17 14 redundant or obsolete. However, what is new is the influence of climate
18 15 change and associated environmental policy on some property assets.
19 16 The article deliberately combines conceptual agendas often studied in
20 17 isolation. Theories of path dependence and lock-in are used to
21 18 understand the problematic traction of climate change legislation within
22 19 traditional real estate institutions. The implications of this situation, the
23 20 potentially hidden systemic socio-economic reach of stranded assets, is
24 21 then considered through the lens of contemporary debates of
25 22 financialisation. Socio-technical system theory, as it relates to
26 23 contemporary energy policy regimes, is then examined to connect
27 24 persistent lock-in with financialised global investment markets. The
28 25 article then posits how associated legislation could be used to capture a
29 26 global picture of stranded assets in real estate. Revealing the stranded
30 27 asset exposure should be a concern to real estate investors and those
31 28 charged with managing such assets. However, more optimistically this
32 29 potential risk may provide the catalyst for energy efficient transition in
33 30 the built environment. The article concludes by outlining an
34 31 interdisciplinary research agenda for stranded assets in global real estate.

40 32 **Key words:** Stranded assets, real estate, environmental policy, path
41 33 dependence, financialisation, socio-technical systems, climate change.

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47 34 **1. Introduction**

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49 35 Stranded assets are assets that have, 'suffered from premature or
50 36 unanticipated write-downs, devaluations or conversions to liabilities'
51 37 [Caldecott, 2016]. The scope of this article focuses on the issue of climate-
52 38 related risk and opportunity, primarily the under researched idea that
53 39 climate change policy, as it relates to energy transitions, could induce the
54 40 stranding of some conventional real estate assets in the global real estate
55 41 market. The underlying research question considers,

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58 42 *To what extent is the global real estate market exposed to the energy*
59 43 *policy related stranded asset threat?*

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61 44 Upon answering the underlying research question, the primary aim of the
62 45 article is to introduce the topic of climate-related 'stranded assets'
63 46 [Caldecott, 2017] into the heterogeneous global real estate asset class for
64 47 the first time. Necessarily, the article is broad in nature, providing a
65 48 commentary on stranded assets in the global real estate market, with the
66 49 intention of acting as a staging post for a new research agenda into how
68 50 environmental related risk might transpire and strand real estate assets.

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70 51 The main sections set out a new conceptual agenda that, firstly, reveals
71 52 and then, secondly, seeks to understand stranded assets in global real
72 53 estate markets. It originally combines theories of path dependence,
73 54 financialisation and socio-technical systems with energy performance
74 55 labelling to reveal the nature, magnitude and reach of stranded assets in
75 56 global real estate for the first time. The article then reflects on these
76 57 findings to set out an international research agenda for stranded assets
78 58 in global real estate research. This research agenda expands upon the
79 59 initial conceptual process outlined in this article and posits some research
80 60 opportunities relating to climate-related stranded assets. This section
81 61 moves beyond the mostly Western European and North American
82 62 perspectives in the main body to consider how a global research agenda
83 63 could be meaningfully tackled with alternative methodologies and
84 64 conceptual perspectives. The article then concludes by reflecting back on

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92 65 the underlying research question and considers some limitations to the
93 66 research.

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95 67 The motivation for this research is to provide a sound basis for policy
96 68 makers when governments and practice evaluate ideas for climate
97 69 change transition and adaptation in the real estate sector. For those
98 70 property professionals involved in the day-to-day management of real
99 71 estate assets in the developed world, the article provides an approach to
100 72 understanding the wider significance of climate-related threats, which
101 73 we hope, will contribute to more knowledgeable and effective practice in
102 74 relation to real estate-based stranded assets. Expanding knowledge in
103 75 this area will help city leaders, investment portfolio and asset managers
104 76 in mature urban areas deal with the challenges of adapting an ageing
105 77 property stock.

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108 78 However, it is also hoped that this approach will help city leaders and
109 79 property professionals dealing with the demands of accelerating
110 80 urbanisation in the less developed world, which requires an
111 81 understanding of urban development processes and the potential impact
112 82 of stranded assets. Encouragingly, less developed countries may have the
113 83 potential opportunity to leapfrog climate-related stranded asset risk in
114 84 real estate. This is because their built environments are often relatively
115 85 younger. The fifth section argues that these locations may be able to
116 86 bypass intermediary stages of urban development, avoiding the costs of
117 87 adaptation, and potentially becoming leaders in sustainable property
118 88 through new urbanisation and smart city development. However, in line
119 89 with the arguments of Perkins (2003), the article cautions against overly
120 90 optimistic interpretations of leapfrogging that ignore the context of such
121 91 locations in relation to project goals, technology and institutional
122 92 capacity when outlining a research agenda for stranded assets in global
123 93 real estate.

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128 94 Conceptually, the article also aims to demonstrate how the afore
129 95 mentioned theoretical agendas, predominantly found in social science
130 96 and often studied in isolation and/or in discreet locations, can be
131 97 combined to shed new light on the traditional econometric and technical

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137 98 perspectives found in global real estate studies and practice based
138 99 investment methodologies in a novel way.
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140100 **2. Theoretical perspective**

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142101 In order to answer the research question, and in part response to the call
143102 of Eames et al, (2017) for more cross-transfer of learning and multi-
144103 disciplinary research in sustainability transitions, the article links research
145104 in energy policy and built environment retrofit to introduce the stranded
146105 asset issue. It then strategically combines conceptual agendas seen in the
147106 respective path dependence, financialisation and socio-technical system
148107 fields to reflect upon this situation.

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151108 The article situates the emerging stranded assets literature with theories
152109 of path dependence and lock-in developed in economic geography to
153110 understand the impact of climate change legislation within traditional
154111 real estate institutions and the persistent silence of stranded assets.
155112 During the early 1990s path dependence was introduced as a new
156113 alternative to the orthodox neo-classical economic perspective based on
157114 optimisation and equilibrium (Henning et al, 2013). Concurrently, it also
159115 took route in the history of technology field. Arthur (1989) separated the
160116 economics discipline into 'conventional' economics that did not recognise
161117 historical contingency and 'contemporary' economics which embraced
162118 path dependence and evolution (Henning et al, 2013).

164119 The latter perspective emphasises that decisions are not only influenced
165120 by present conditions but also include decisions that have been taken
166121 previously. These interpretations are now widely used within the retrofit
167122 and energy transition literature (see Dixon et al 2018) to understand how
168123 socio-technical systems and regimes endure and are potentially
170124 disrupted. This article uses Grabbers (2003) treatment of the issue to
171125 understand how political, functional and cognitive forms of lock in
172126 coalesce to strand assets in real estate practice.

174127 The article then reflects on the systemic socio-economic reach of
175128 stranded assets through the lens of contemporary theories of
177129 financialisation developed in urban studies. Fields (2018:119) recently

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182130 defined financialisation as 'an idea that has taken hold as a means of
183131 understanding the distinctive role of finance in contemporary capitalism,
184132 and its influence on space, the economy, governance and everyday life.'
185133 In recent decades, the financialisation literature has emerged as a
186134 powerful medium for understanding how assets are securitised and then
187135 invested through international capital markets. For example, Weber
188136 (2015) has investigated the Tax Increment Finance agenda in North
189137 America, Aalbers (2012) has investigated the international mortgage
190138 securitisation market and the sub-prime mortgage fallout, while Gotham
191139 (2017) has considered disaster relief funding. More recently, Fields (2018)
192140 and Beswick and Penny (2018) have examined housing finance and local
193141 asset backed vehicles, while Christophers (2019) has started to think
194142 about how institutional investors think about fossil fuel risk. However, as
195143 Fields (2018) argues, the process of financialisation is often poorly
196144 understood and utilised as an explanation in itself without any
197145 investigation into how the process of financialisation occurs
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201146 In response to this criticism of financialisation, the article then moves on
202147 to examine contemporary energy policy and how associated socio-
203148 technical legislation could be used to capture a global picture of stranded
204149 assets in real estate, connecting the persistent behaviour of practice that
205150 ignores stranding into the global capital markets that are implicit in
206151 financialisation. This examination responds to the earlier critique of Fields
207152 (2018) but also by investigating energy performance certificates and
208153 associated legislation, that of Latour (1999) in to 'black boxing' technical
209154 artefacts that, due to their success, are often ignored by social science
210155 research (Swan, 2013).
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214156 Drawing on the work of [De Greene , 1973], [Eames et al, 2013] and
215157 [Dixon et al, 2018], energy performance labelling is considered an
216158 example of a potentially global integrative socio-technical regime or
217159 system connecting society's complex technical procedures (building
218160 design) with human behaviour (building use). In this article, a socio
219161 technical regime is considered 'a shared set of rules and routines
220162 embedded in socio-technical systems to ensure that they can provide the
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relevant social function' (Schot et al, 2016:16061). While the closely related socio-technical system rests upon the, 'premise that social and technical systems are co-constituted and co-evolve across time and space' (Lowe et al, 2017:5). Geels (2005:5) suggests that socio-technical systems display the following characteristics in society, 'technology, regulation, user practices and markets, cultural meaning, infrastructure, maintenance networks and producing systems.' In this sense, it is also important to note that real estate markets, the process of financialisation and global investment markers can also be considered socio-technical systems themselves within a complex adaptive system.

The energy labelling system functions as a method for understanding society's energy use, and through consequent minimum energy performance legislation, how such use can be monitored and improved. However, the same regime system has the potential to hardwire and connect valuation risk into global capital markets. In this sense, EPCs and associated minimum energy rules prime already financialised real estate assets (for example through international mortgage markets, Real Estate Investment Trusts, Unit Trusts and Property Companies) for stranding. EPCs, in this sense, play the dual role of conceptually connecting lock-in with financialisation but also, empirically, the potential role of capturing the magnitude of the stranding issue in global real estate. Therefore, the nature of the research is part conceptual, in setting out a framework for understanding stranded assets and part empirical in using energy performance certificates to capture the size of the stranded assets threat.

In this paper, real estate is taken to mean, broadly, all residential, commercial, and operational property. This is a broad characterisation that is used to help reveal the stranding problem in global real estate. The authors concede that this definition simplifies the inherent variability found within respective real estate assets and return to this issue at the end of the article in suggesting opportunities for further research. Principally, the focus for study is the UK; however, comparisons are made internationally, and key distinctions are made between developed and less developed countries.

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The authors note that the traditional binary distinction between developed and less developing countries is problematic, certainly over simplifying the rich diversity of characteristics found within and between each relative classification. Indeed, the World Bank dropped the categories ‘developed’ and ‘developing’ from its economic vocabulary in 2016. Instead, the authors use the broad distinction of ‘developed’ and ‘less developed’ to compare the relative maturity of built environments in such locations, rather than making any assumptions about the respective locations economic or social capacity. The authors then revisit this distinction at the end of the paper suggesting alternative measurements and perspectives as a rich opportunity for further study.

3. Climate change and nature of real estate markets

The article observes that stranded assets are not new in real estate, as the changing consumer demand of occupiers has regularly rendered property assets redundant or obsolete - exhibiting the creative destruction outlined by Joseph Schumpeter in 1950. However, what is new is the influence, systemic reach and disruption of climate change and associated environmental policy on some property assets, related capital markets (at the macro scale) and individual communities (at the micro scale) that are reliant on homes to live, and commercial property to work.

At the same time as the global emphasis on sustainability, the international real estate sector is going through its own set of structural growing pains in response to dynamic changes in residential and business practices - potentially coalescing with and exacerbating the climate-related stranded asset issue. For example, the appetite for smaller commercial floorplans in the office sector, the impact of the internet on the retail sector, and the disruptive influence of new property technology on conventional real estate living and working conditions have all increased uncertainty in the global real estate market.

In response to climate-based threats and associated environment policy, there is now pre-emptive need for new arrangements of land, unconventional forms of buildings, and creative adaptations to the

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317 228 existing property stock to combat the threat of devaluation [Wilkinson et
318 229 al, 2107], [Eames et al, 2017]. However, at the same time, there are
319 230 several opposing forces that make pre-emptive action involving energy-
320 231 efficient retrofit measures (or new sustainable construction) difficult in
321 232 the developed world. Grabher's [1993] treatment of path dependence
322 233 and 'lock-in' is a suitable analytical framework to understand this
323 234 situation. Setting aside the sheer cost involved in adapting real estate
324 235 assets in the face of climate change [Eames et al, 2017], path dependence
325 236 and lock-in is concerned with the persistent behaviour of people, society,
326 237 business, and locations as they maintain and reinforce historical
327 238 behaviour in contexts that are significantly different to the original
328 239 historical circumstances [Henning, 2013]. Grabher [1993], researching in
329 240 the field of regional economics, describes three interrelated types of
330 241 'lock-in': political, functional, and cognitive lock-in. These same
331 242 constructs can also be used to help explain the existence and silence of
332 243 stranded assets in global real estate debate and practice and some of the
333 244 drags upon retrofit in the built environment.

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335 245 Political lock-in explains circumstances in which traditional courses of
336 246 development are retained and reinforced by pre-existing stakeholders
337 247 and institutions, inhibiting adjustment to new considerations and policy
338 248 directives. Bishop and Williams[2012] and Henneberry [2017:1-2]
339 249 illustrate this situation when they argue that cities in the developed world
340 250 have gradually become more 'formalised and permanent'. Proliferating
341 251 layers and intensities of legislation '(some with a long history but most
342 252 introduced in the 20th Century) covering building construction, fire
343 253 prevention, public health, building conservation and land use planning
344 254 have solidified the urban built environment'. This echoes the recent work
345 255 of [Dixon et al, 2018], who see individual cities, as a complex mix of
346 256 homes and businesses, and the product of many hundreds of years of
347 257 evolution and growth that become locked into patterns of resource use
348 258 that can no longer be justified. This intransigent situation makes it more
349 259 difficult for the existing built environment to change. This is subsequently
350 260 later compounded by the slow replacement of real estate stock (IRENA,
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362261 2017) which typically only accounts for 1-3% of stock per year (Zhenjun
363262 et al, 2012; Eames et al, 2013;Itani et al, 2013).
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365263 Cognitive lock-in relates to collective ideas and beliefs that inhibit the
366264 acceptance of new ideas - overlaying physical rigidity in the built
367265 environment is a climate of institutional inertia. Muldavin [2010] argues
368266 that although important steps have been taken, the real estate sector is
369267 struggling to confirm the value of sustainability in property investment.
370268 Although there have been amendments made to the RICS Red Book
372269 [2013], alongside a Guidance note on Sustainability and Commercial
373270 Property Valuation [2014], it has been difficult for the traditionally
374271 sluggish real estate sector to take on board sustainability objectives.
375272 Primarily, this is because there has been no demonstrable enhancement
376273 to return [Dixon, 2014]. This is because the imperfect implications of
378274 stranded assets - implicit in sustainable development - are very awkward
379275 for mainstream real estate research to digest. Traditional paradigms in
380276 real estate economics and related practice, for example the valuation of
381277 property, and modern portfolio theory are anchored in the maximising
382278 presumptions of the rational investor. It is not straightforward to capture
384279 the cost or potential premium afforded by sustainability, as valuation is
385280 typically backward looking based upon retrospective property valuation
386281 [Diaz and Hansz, 2001]), resulting in a lack of scrutiny by valuation
387282 professionals [Lützkendorf and Lorenz, 2005], [Lorenz and Lützkendorf,
388283 2011], [Michli et al, 2016]. Similarly, real estate investors make decisions
390284 and monitor progress against historical performance benchmarks and
391285 indices, such as those provided by the Investment Property Databank
392286 (IPD) and CB Richard Ellis.

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394287 Functional lock-in, in this case, relates to the too-close connection
395288 between historical building functions and worth, which inhibits
396289 consideration of external change. Illustrating this situation in the real
397290 estate sector, the common treatment has been to situate the analysis of
398291 stranded assets in the depreciation and obsolescence literature. There is
400292 a variety of informative applied depreciation studies by [Baum, 1991],
401293 [Baum and McElhinney, 1997], [Dixon et al, 1999] [Dunse and Jones,

2002], [Andrew and Pitt, 2006], [Crosby and Devaney, 2006], [Mansfield, 2009], and [Crosby et al, 2011]. However, broadly speaking, in this perspective functional real estate assets grow old, become less productive, and must then be improved or replaced. Through this process, loss of value occurs gradually in a typically linear fashion related to the original function of the building rather than under external conditions of sudden market disruption [Christensen, 1997].

On one hand, the potential stranded asset threat, initially associated with value of unburnable carbon stocks [Krause, 1990], [Carbon Tracker Initiative, 2013] and more recently following the Paris Agreement [Covington, 2013], has the potential to blow this market lethargy wide open. This is because, until now, sustainability has mostly been seen as an altruistic choice or government concern associated with environmental objectives rather than business necessity. On the other hand, traditional real estate valuation methods are still based on the most recent comparable transaction advice rather than any forecast of sustainability value or fossil fuel liability, resulting in a stranded asset knowledge deficit. Illustrating the consequences of this situation, [Warren-Myers, 2012] argues that without confirmation of environmental value, sustainable investment (or fossil fuel disinvestment) will be constrained in the real estate sector. The next section, in part, aims to fill this gap in knowledge by connecting impact of path dependence and persistent behaviour into global capital markets through the process of financialisation.

4. Stranded assets and the global real estate market

The following section brings forward the path dependent traditions in real estate practice and connects this into the financialised reality of global real estate investment markets. This is in order to reveal the potential gravity of stranded assets but also to show how ingrained practices in real estate have the potential to create risk in global capital markets. In recent years, climate-related stranded assets have received international attention from the UN [McGrath, 2014], the North American government [Friedman, 2014], the OECD [Gurría, 2013], the

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452327 Inter-American Development Bank [Caldecott, 2016], the G20 Financial
453328 Stability Board, and the Bank of England [Carney, 2015]. However, the
454329 same issue has received very little attention in the real estate sector
455330 [IRENA, 2017 is a notable exception), even though the real estate sector
456331 shares and potentially intensifies many of these same risks downstream.
457332 Given that real assets make up a large part of total global investment
458332 worth and are a significant store of national, corporate, and individual
459333 wealth, the omission of real estate from the stranded assets discourse is
460334 a significant omission.
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463336 Traditionally, real estate assets share many of the same imperfect
464337 investment characteristics as fossil fuel assets in relation to liquidity,
465338 fungibility, and transmission of potential risk. For example, both assets
466338 classes are heterogeneous, typically, no two assets are the same and they
467339 take considerable initial investment to exploit, there are few buyers and
468340 sellers in the market place (due to cost and location), market entry and
469341 exit is difficult (due to ownership monopolies, the illiquid nature of assets,
470342 and government legislation), and both types of asset are typically fixed in
471343 location (either under it or built on top of it).
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474345 The respective asset classes are also interrelated. Traditionally,
475345 residential and commercial property assets have been powered by fossil
476346 fuel-dependent heating and ventilation systems. Furthermore, the urban
477347 sprawl associated with suburban residential property, out-of-town office
478348 parks, and retail centres, has evolved in tandem with the fossil fuel-based
479349 automobile. There is also a distinct and highly expensive set of
480350 operational property assets that has been constructed to directly serve
481351 the fossil fuel sector, for example, coal-fired power stations, which are
482352 typically highly leveraged (exposed to debt finance) and have no obvious
483353 alternative use [IRENA, 2017].
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487355 The global value of real estate is \$217 trillion (of this \$162 trillion dollars
488356 is residential, \$29 trillion dollars is commercial and \$26 trillion is
489357 agricultural land), roughly 2.7 times global GDP, making up roughly 60%
490358 of all mainstream investment assets [Savills, 2016]. Furthermore, the
491358 value of the new construction market will be \$17.5 trillion in 2030, an \$8
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497360 trillion increase on present-day values [Oxford Economics, 2015]. In large
498361 part, the volume of real estate assets in global investment portfolios and
499362 the circulation of the same assets in international capital markets is down
500363 to increasing levels of financialisation outlined in recent years by [Weber,
501364 2010], [Aalbers, 2017], [Christophers, 2017] and [Fields, 2018].

503365 Hitherto, stationary physical real estate assets have been increasingly
504366 repackaged into a rash of financial products and funds, including
505367 derivatives, real estate investment trusts, and debt vehicles. This process
506367 has been intensified during periods of political and fiscal uncertainty
507368 because real estate has increasingly replaced Government Bonds as a
508369 provider of fixed income in investment portfolios. This has expanded the
509370 tentacles of property asset value throughout global finance networks.
510371 The implication is that stranded real estate assets provide a vehicle for
511372 intensifying the threat of climate-related stranded assets because they
512373 reach further into and have broader exposure in capital markets than
513374 fossil fuels assets. Look no further than the 2008 global financial crash for
514375 an illustration of the sudden impact and systemic influence of real estate
515376 based financial products. Despite sustainable intervention, including
516377 enhanced insulation, better glazing, and utilising solar power and
517378 biomass, global property stock is still reliant on fossil fuel for heating and
520379 ventilation. This perspective sheds a new light on contemporary debates
521380 of financialisation that typically analyse the creation of new asset classes.
522381 This article looks at a product, global real estate, which has been
523382 financialised for many decades and considers how this previously
524383 relatively stable system is at risk of disruption.
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528385 The following section utilises the outputs of international building energy
529386 performance legislation to outline a model for understanding climate-
530387 related stranded asset exposure. The same legislation and EPC regime is
531388 also the conceptual bridge that connects path dependence into the
532389 financialised global real estate market.

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542**5. Climate-based real estate legislation**
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544 Global real estate is essential for urban development. However, it
545 expends physical resources and is the origin of considerable emissions. A
546 conservative estimate is that global real estate consumes 40% of global
547 energy annually and accounts for more than 20% of international carbon
548 emissions [World Economic Forum, 2016]. As part of international efforts
549 to reduce carbon emissions, real estate and its associated built
550 environment has been identified as a major contributor toward planetary
551 warming [IPCC, 2014]. For example, the UK government aims to reduce
552 UK real estate CO2 emissions to close to zero by 2050 to attain its energy-
553 efficiency targets. This aim has been repeated around the world and is an
554 example of an attempt at a socio-technical system transition.
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557 Consequently, in recent decades, the real estate sector has been at the
558 forefront of climate change legislation, designed to reduce its impact on
559 the global environment. Environmental labelling, endorsement based
560 and comparative [Reed et al, 2009], has been a central tool in reducing
561 the environmental impact of building stock. Typically, environmental
562 labelling has adopted either a multi-criteria sustainability approach or a
563 narrower focus on energy [Sayce et al, 2010]. In the 1990s, the BREAAAM1
564 tool led the way in the UK (multi-criteria), soon to be followed in France
565 by the HQE2 model (multi-criteria), the Swiss Minergie3, and the North
566 American Energy Star4 (both energy). In the 2000s, these models were
567 joined by further multi-criteria schemes, LEED5 (North America),
568 CASBEE6 (Japan), Green Globe7 (Canada), and Green Star8 (Australia).
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573 Latterly, one of the most comprehensive approaches can be seen in the
574 European Union (EU). Following the 2010 EU Energy Performance of
575 Building Directive, it is mandatory for all European properties to hold an
576 Energy Performance Certificate and monitor their heating and air
577 conditioning (all 28 Member States signed up to this directive). Energy
578 Performance Certificates (EPCs) have a significant relationship with
579 climate-related stranded assets in real estate. They are a key enabler of
580 building improvement, as they have the potential to influence decision
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587425 making in real estate transactions and provide cost-optimal
588426 recommendations for energy performance improvement [BPIE, 2014].
589427 They provide the opportunity for governments to enforce minimum
590428 energy performance standards, and they are an important information
591429 tool for building owners, occupiers, and real estate stakeholders. These
592429 latter two themes form the basis for the remainder of this section. Firstly,
593430 the potential for climate-related legislation to strand real estate assets
594431 will be considered, before, secondly, the information bi-products of
595432 energy performance labels will be assessed for their potential in
596433 measuring stranded asset exposure.
597434

5.1 Climate-related obsolescence

598435
600436 The England and Wales government has used EPCs as the basis for legally
601436 enforceable Minimum Energy Efficiency Standards (MEES), legislated
602437 through the Energy Efficiency (Private Rented Property) (England and
603438 Wales) Regulation Act 2015. These regulations have fixed a minimum
604439 standard for both domestic and non-domestic privately rented property.
605439 Commencing in April 2018, any domestic or non-domestic property that
606440 is available to let with an energy performance rating below E (those
607441 properties with F and G ratings) has been deemed illegal to let – in 2020,
608442 the same rule will apply to residential property. In England and Wales, it
609443 is estimated that 10% of residential property stock (£570bn) and 18%
610444 (£157bn) of commercial stock are under this threshold. In addition, the
611444 Government in England and Wales is also considering the merits of
612445 committing to a forward plan for MEES. This would mean that the
613446 minimum energy performance regulatory standard is increased over time
614447 in order to provide medium - to long-term certainty regarding when the
615448 progressive standards will apply and when any necessary physical
616449 improvements will need to be made [Department of Energy and Climate
617449 Change, 2014].
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623454 From 1 April 2023, these regulations will apply to all non-domestic
624455 property, not only those agreeing a new let, lease renewal if an EPC is
625456 already in place, or tenants wishing to sublet [Green Construction Board,
626456 2014], [The Non-Domestic Minimum Building Energy Performance
627457

Standards Working Group, 2014]. Failure to meet these new rules, for example, the illegal letting of a sub-standard property, will result in a minimum fine of £150,000. There are several potential exemptions to MEES, primarily:

- Any building improvement that would alter the character or appearance of an historical (in a conservation area) or listed building,
- Where energy efficient improvements would reduce market value by more than 5%,
- The improvements do not pay for themselves through energy cost saving within a seven-year time frame,
- If the landlord cannot get consent from planning authority or incumbent tenant,
- Temporary buildings and detached buildings under 50 sqm.

To protect against MEES avoidance techniques, all exemptions must be held on an Exemption Register. The implication is that any sub-standard building will still be publicly named and shamed and may suffer yield and value depreciation. The MEES in England and Wales indicates a potential future trajectory for international property legislation, in which governments tighten up on building emissions in order to achieve climate change targets. Using the minimum energy exposure figures in England and Wales as a proxy for international energy policy and combining them with the recent estimate of global real estate value provided by [Savills, 2016], it is possible to gauge global real estate exposure to climate-related stranded assets. If all international governments followed the same strategy, the risk value for residential real estate property assets would be \$16 trillion and \$5 trillion for global commercial assets.

However, the introduction of MEES has not been without difficulty. Potentially 70% of EPC ratings in England and Wales could be incorrect (either too low or too high) due to the inconsistent quality of assessments [Hobbs, 2013], [Hosgood, 2014] and the evolving nature of the underlying

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677489 method of calculation (the Simplified Building Energy Model – SBEM).
678490 Furthermore, the government has abandoned the flagship finance
679491 mechanism that accompanied MEEs in the residential sector, the Green
680492 Deal Finance Model, and it was never introduced for commercial
681493 property. The consequence is that the England and Wales Government
682494 has sent out a very strong policy signal in favour of building improvement
683495 but has removed the primary financial means of doing so.
684496

685 686496 **5.2 Exploiting climate change legislation to create an information** 687497 **baseline for real estate stranded assets** 688

689498 The first stage in tackling climate-related stranded assets in the real
690499 estate sector must be identifying their existence. IRENA [2017] have
691500 proposed an ambitious methodology for assessing the global real estate
692501 stranding asset exposure. The method utilises estimates of existing floor
693502 space, forecasted new building space, and natural demolition rates to
694503 quantify for the first time climate-related stranded assets in building
695504 stock, the impact of delayed policy action, and the cost of retrofitting sub-
696505 standard properties in response to climate-related policy action. The
697506 method lays important foundations for studying the impact of fossil fuel-
698507 related stranded assets in the real estate sector, for the first time linking
699508 the upstream fossil fuel sector into downstream real estate assets.
700509 However, due to the lack of information transparency in the real estate
701510 sector [Fuerst et al, 2011], IRENA [2017] concede that the method rests
702511 on a number of necessary estimates and presumptions and utilises a
703512 broad econometric methodology. There is considerable scope to build on
704513 this method with more detailed data sets, information resources and
705514 conceptual enquiry found in the social sciences.
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707516 The granularity and scope of the IRENA model could be significantly
708517 enhanced by using already-existing energy labelling information. For
709518 example, the mandatory EPC information held in the EU Building Stock
710519 Observatory and English and Wales EPC registry could be used to provide
711520 accurate accounts of energy use, floor space, building retrofit advice (and
712521 cost), type of property, and location. This could then be augmented with
713522 more information from the Building Performance Data Base in North
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722522 America and the National Australian Built Environment Rating System. In
723523 principle energy performance labelling provides an opportunity to
724524 accurately measure climate-related stranded asset exposure in the
725525 developed world. However, information is less readily available in the less
726526 developed world. Those areas of the world with less transparent
728527 property markets, for example China (the Three Star Rating Building
729528 System) and South America (for example the RTQ-C and RTQ-R
730529 methodologies in Brazil), are increasingly adopting building energy
731530 performance standards, which reveal the opportunity for comprehensive
732531 international energy performance data bases in the future.
733531
734532 Information generated from mandatory EPC assessments could be taken
735532 further. Issues of consistency and accuracy (a problem shared with the
736533 wider real estate market) significantly hamper meaningful assessment of
737534 stranded assets and energy performance in real estate stock.
738535 Increasingly, contemporary real estate data sets include Unique Property
739536 Reference Numbers (UPRN). UPRNs enable the linking of disparate data
740537 sets to provide more powerful, multi-criteria data sets and provide a
741538 consistent identifier throughout the building life cycle – from initial
742539 planning consent to final demolition. However, EPCs do not carry a
744540 requirement for a UPRN; this is a missed opportunity. For example, in
745541 England and Wales, the presence of a consistent UPRN would enable the
746542 linking of EPC information to National Valuation data sets. Each property
747543 in England and Wales is valued every five years for taxation purposes;
748544 linking both data sets would facilitate accurate measurement of energy
749545 use, floor space, and value and would assist, in part, the measurement of
751546 real estate-related stranded assets exposure to government revenues.
752547 Most developed countries typically derive some of their taxation from
753548 property, indicating the international potential for this coupling. This
754549 would potentially lead to a socio-technical energy performance baseline,
755550 which could be used to benchmark and monitor the risk of climate-
757551 related stranded assets and more generally the value of sustainability – it
758552 could also be used to potentially police transition through taxation. This
759553 would be an important innovation, as it would increase the overall quality
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767555 of property valuation by integrating carbon into statutory methods of
768556 property valuation.
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770557 **6. Developing a stranded asset research agenda in global real estate**

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772558 The first challenge for global real estate stakeholders, their professional
773559 bodies and academics is in connection to the recognition of climate-
774560 related stranded assets. This, in part, involves creating the informational
775561 baselines that reflect the existence and cost of stranding – a methodology
776562 has been outlined in this article. It also necessitates going beyond
777563 technical and atheoretical concepts of building energy to consider how
778564 EPCs and associated legislation can be an important conceptual device
780565 for connecting disparate academic agendas. An initial informational
781566 baseline only provides a broad measurement of climate-related stranded
782567 asset exposure in parts of the global real estate market. Research into
783568 stranded assets in the global real estate markets demands an
784569 international perspective and potentially a different set of methodologies
786570 and research techniques.
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788571 This article has strategically blended theories of path dependence,
789572 financialisation and socio technical systems in order to understand and
790573 reveal the stranded asset issue in global real estate. These theories are
791574 traditionally studied in isolation. However, this tactic has been necessary
792575 to reveal the global issue that may not have been possible through
793576 prescribed single case study, econometric or technical research. The
794577 authors argue that further blending of multi-disciplinary conceptual
795578 domains will be necessary to understand the variable contexts of
797579 stranded assets.
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799580 In particular, these new perspectives should be cognisant of the very
800581 different and often variable contexts in the developed and less developed
801582 world. Real estate, as it relates to energy use, in the less developed world,
802583 particularly in rural locations, is diverse – influenced by variation in
803584 population size, economic activity, resource levels, and energy profile.
804585 Due to the rapid nature of development in these locations, there is also a
805586 congested policy landscape, which makes focusing on climate-related
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812587 stranded assets problematic. Not least, the thorny subject of whether
813588 such locations should face the same stringent climate standards as the
814589 developed world when they have not had the opportunity to exploit the
815590 economic growth associated with fossil fuel use. In contrast, physical real
816591 estate development and supporting professional practice is well
817592 established in the developed world, anchored in rigid functionality and
818593 institutions – due to the age of the built environment.

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821594 Such regions can have key geographical features, which aid fossil fuel
822595 divestment in real estate. For example, generous space and excellent
823596 access to sunlight has the potential to aid the exploitation of wind and
824597 solar energy (in contrast, energy use retrofitting in the western world is
825598 exacerbated by less proximity to natural resources). This resource
826599 landscape is particularly advantageous in those locations – for example
828600 rural India – where it is difficult or unduly expensive to develop fossil fuel
829601 infrastructure or to interface with a national energy grid. This awkward
830602 situation is primarily related to the sheer logistical challenges associated
831603 with expansive and unforgiving locations and/or the paucity of capital
832604 finance.

834
835605 The stranded asset situation in the less developed world also needs to be
836606 understood in the context of vastly differing circumstances. For every
837607 exemplar self-contained smart city, for example Masdar City (in the
838608 United Arab Emirates) or the Songdo International Business District (in
839609 South Korea) – exhibiting high-tech digital infrastructure, carbon-neutral
840610 buildings, green urban planning, and abundant capital finance – there are
841611 many more largely rural locations, for example Xinjiang Province in China
842612 and Bihar State in India, exhibiting marginal and fragmented locational
844613 attributes. They are quite literally operating off the conventional energy
845614 grid and outside conventional fossil fuel infrastructure routes. In these
846615 locations rather than overarching conceptual and empirical methods,
847616 such as those deployed in this article, more situationally specific enquiry
848617 may be suitable, for example case study and ethnographic enquiry.
850618 Concurrently, it is not a given that smart city developments are
851619 necessarily also clean in the energy sense. Consideration should be given

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857620 to whether developments of this nature compliment energy directives
858621 and sustainability requirements.

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860622 However, all these locations, broadly, are united by rapidly increasing
861623 levels of population and concurrent energy demand, which has put these
862624 locations on a rapid energy provision trajectory. Understanding this
863625 trajectory provides a potential opportunity to minimise climate-related
864626 stranded assets through leapfrogging before they happen whilst
865627 achieving the decarbonisation agenda [IRENA, 2017]. This is possible
866628 because large amounts of the built environment in less developing
867629 locations has not been constructed yet. However, this research needs to
868629 be approached critically, recognising that leap frogging is not a given and
869630 is contingent upon the technology available for investment; relative skills
870631 and institutional capacity; and, most importantly, political stability and
871632 will (Perkins, 2003). Indeed, Perkins (2003:) argues, “national
872633 governments will need to challenge entrenched domestic and foreign
873634 interests whose preferences lie, to a greater or lesser extent, along a
874635 business as usual path”.

875636
876637 To support this more critical approach, the authors suggest additional
877638 engagement with conceptual domains that interrogate emerging
878639 governance profiles in such locations; that seek to understand relative
879640 and emerging skill and institutional capacities, for example as they relate
880641 to creating an energy performance regulatory framework. This would be
881642 complemented by research that moves beyond simple binaries of
882643 developed and less developed counties in order to utilise more precise
883644 alterative measures such as the United Nations Human Development
884645 Index and that acknowledge the socially produced uniqueness of distinct
885646 real estate markets (Guy and Henneberry, 2000). This multidisciplinary
886647 approach to researching stranded assets in real estate will help
887648 investigate the following key questions in relation to mitigating and
888649 reversing stranded assets.

889650 The global real estate sector is hugely disparate – how might climate-
890651 related stranded assets be more or less important for different types of
891652 societies, geographies and heterogeneous property assets. This article

901
902 653 has broadly discussed global real estate, merging residential and
903 654 commercial property into one bulk class. In reality, these two asset
904 655 classes are completely different and should be considered as two
905 656 separate areas for study. Small individual investors with relatively small
906 657 financial stakes - many of which have the potential to avoid the legislative
907 658 radar, dominate the residential real estate sector. How will the costs of
908 659 retrofit, and the likely increase in rent, be balanced against a concurrent
909 660 demand for low cost housing demand. In contrast, commercial real estate
910 661 is typically owned by companies, conglomerates and investment bodies
911 662 who have a much larger financial stake and corporate social
912 663 responsibility.

913 664 This critical approach also has the potential to help uncover the
914 665 relationship between the normal refurbishment cycle of property and the
915 666 problem of stranding. Although the building replacement cycle is
916 667 notoriously sluggish, the occupation of buildings, particularly in the
917 668 commercial sector, is increasingly dynamic and short-lived. Could the
918 669 new era of short leases and increased opportunity for landlord/tenant
919 670 negotiation at lease renewal help ameliorate the problem of climate-
920 671 related stranding?

921 672 The approach will also help examine what the evolution of urban
922 673 locations tell us about the trajectory and potential amelioration of
923 674 stranded assets. New understanding in this area could help inform
924 675 intervention and so-called leapfrog development in the less developed
925 676 world before fossil fuel dependency is ingrained. Moreover, it can help
926 677 uncover which countries are pursuing minimum energy measures in the
927 678 developed world. For example, how many of the 28 European Union
928 679 Member States have laid down legislation to achieve this aim. This
929 680 research agenda could also help inform how considerations of
930 681 sustainability, in particular it's pricing, could be aligned with the problem
931 682 of stranded assets. Part of this must involve understanding which parties
932 683 will be paying for the retrofit challenge and where they will get the
933 684 funding from. Nothing will happen with stranded assets unless the money
934 685 is available to do the retrofit improvements. Outlining the cost risk of

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947686 stranded assets in this paper, helps justify this expenditure. Finally, this
948687 new research could help consider, what other factors (besides
949688 environmental legislation) cause stranding in global real estate markets.
950689 For example, do certain types of property, markets, and locations have
951690 systemic risk because of their underlying characteristics.

953691 **7. Conclusion**

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955692 In response to the underlying research question,

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957693 *To what extent is the global real estate market exposed to the stranded*
958694 *asset threat?*
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960695 The article has combined conceptual agendas in path dependence theory,
961696 financialisation research and socio-technical system studies to reveal a
962697 potential risk value for residential real estate property assets of \$16
963698 trillion and \$5 trillion for global commercial assets. The relatively novel
964699 engagement with the path dependence and lock in literature proves that
965700 history and ‘how we got where we are’ is important in understanding
966701 global real estate markets, built environments and related institutions.
967702 Indeed, our research suggests that traditional ways of working are locked
968703 into regressive valuation methodologies and that this, in part, accounts
969704 for the silence afforded to stranded assets in real estate practice. Socio-
970705 technical system theory has then been used to show how Energy
971706 Performance Certificates and associated Minimum Energy regulation,
972707 have the potential to hardwire and connect valuation risk into global
973708 capital markets. Concurrently, the informational bi-products of Energy
974709 Performance Certificates have been used to reveal the potential
975710 magnitude of stranded assets.

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977711 The utilisation of financialisation as an overarching catalysing concept in
978712 global capital markets has then helped connect the property practices
979713 and techniques in the global real estate market. This research has
980714 revealed a new global asset risk in parts of global real estate that have
981715 been financialised for many decades. This presents a new emphasis for
982716 financialisation research. Contemporary research typically focuses on
983717 newly financialised assets. For example, Weber (2015) and Fields (2018)

991
992718 have revealed new asset classes recently – primarily related to Tax
993719 Increment Finance and Single Family Rental assets. This research reveals
994720 what may happen to newly financialised products further down the line
995721 following disruption and reconfiguration.
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997722 The article argues that exposing the stranded asset threat could play a
998723 positive role in provoking the disruptive sustainable urban retrofit
999724 proposed by Dixon et al (2018). Connecting the “what is needed with the
1000725 how it can be implemented” at the global level. Attitudes could change
1001726 very quickly following the 2018 minimum energy performance legislation
1002727 in England and Wales (and similar minimum energy performance
1003728 initiatives elsewhere in the world). It can be speculated that rapid
1004729 devaluation in certain property assets could ensue if the legislation is
1005730 robustly enforced. If revaluation is significant in size and speed this could
1006731 affect values and behaviour in other international markets, in particular,
1007732 those areas with similar property stock characteristics in terms of vintage,
1008733 heating, ventilation and air-conditioning, and construction type.
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1012734 Adapting theories of lock in and then echoing the recent arguments of
1013735 [Silver, 2016], there are two not necessarily mutually exclusive
1014736 explanations for the silence of climate-related stranded assets in global
1015737 real estate markets. First is that the real estate market has digested the
1016738 stranded asset threat and decided that environmental legislation will be
1017739 sufficiently diluted that climate-related stranding will not impact global
1018740 real estate assets. In other words, real estate stakeholders believe that
1019741 the lobbying power of private and public capital held in global real estate
1020742 and the force of the fossil fuel sector will win out against the climate
1021743 change consensus. Under this position, significant policy related change
1022744 ‘just won’t happen’. Indications in the early part of 2019, the time of
1023745 writing, indicate that this maybe the case with little early enforcement of
1024746 the minimum energy rules. Second, the institutions and traditional ‘ways
1025747 of working’ in the real estate market are largely blind to the stranded
1026748 asset threat, locked in to traditional ways of working – they simply do not
1027749 account for it.
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Both positions are untenable, as they leave real estate assets, and the investors and communities they serve, prone to an uncertain future. Adopting the principles of Pascal's Wager, it is rational to plan for potent climate-related policy enforcement. Adapting existing buildings and constructing new developments that are not reliant on fossil fuels, although potentially costlier in the short term, can create a more resilient (and therefore valuable) asset. Ignoring climate change exposes physical real estate assets to the risk of permanent disruption as clean technology becomes more affordable, as social norms and consumer behaviour increasingly accept principles of environmental sustainability, and as investment managers and financiers increasingly demand that companies disclose business model exposure to climate change.

However, in order to begin to understand climate-related stranded assets in global real estate, it is necessary to qualify the research in this article. The wide urban context of the international perspective reveals the need for some cautionary words in relation to the context and content of the findings and conclusions in this article. The empirical approach has necessarily been one of broad review rather than detailed analysis. Moreover, our definition of real estate in this article is simplifying in its approximation - consequently, we must be careful of over-generalisation and simplification. Each international property market contains a variety of comparable but highly specific contexts, which are contingent and socially produced in each case. Furthermore, there are multitudes of factors involved in real estate obsolescence; only one of these is the climate-related stranded assets. Energy policy is only one part of a complex web of actors, interests, and relations, particularly developers but also investors, occupiers, and members of the community who are either directly or indirectly involved in the production and reproduction of global real estate assets. A great deal more research will be needed to fully understand the specific and variegated nature of climate-related stranded assets in the international context.

Yet despite these caveats, we consider that the material within provides a perspective through which a picture of climate-related stranded assets

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1083 in global real estate begins to emerge. In the energy sector, the aim of
1084 legislation is to reduce fossil fuel consumption by leaving existing assets
1085 in the ground and halting the development of new ones. However, the
1086 impact of energy policy on global real estate assets is different. The aim
1087 of legislation is to improve the quality of property and reduce its negative
1088 impact upon the environment. The implication is that those existing
1089 properties reliant on fossil fuels will need to be improved in order to meet
1090 the needs of continued urbanisation – such properties cannot just be
1091 written off as a loss as they would be in the fossil fuel sector. Illustrating
1092 the magnitude of this retrofit challenge, at the turn of the millennium,
1093 [Kincaid, 2002], referring to the UK, argued that the vast majority of 2050
1094 property stock had already been built (some of it centuries ago in mature
1095 urban locations). Reinforcing this argument, [Kelly, 2008] indicates that
1096 87% of current stock will still be standing in 2050. In other words,
1097 developed nations must go back to the future to solve the climate-related
1098 stranded asset problem through adaptation and retrofit. Conversely, less
1099 developed nations may have the opportunity to skip real estate asset
1100 fossil fuel dependency in order to define their own future.

1101 **References**

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1 BREEAM (Building Research Establishment Environmental Assessment Method), first published by the Building Research Establishment (BRE) in 1990, is the world's longest-established method of assessing, rating, and certifying the sustainability of buildings.

2 The Haute Qualité Environnementale or HQE (high-quality environmental standard) is a standard for green building in France, based on the principles of sustainable development.

3 Minergie is a registered quality label for new and refurbished low-energy-consumption buildings. This label is mutually supported by the Swiss Confederation, the Swiss Cantons, and the Principality of Liechtenstein along with Trade and Industry.

4 Energy Star (trademarked ENERGY STAR), originating in North America, is an international standard for energy-efficient consumer products that can be applied to residential and commercial properties.

5 Leadership in Energy and Environmental Design (LEED) is one of the most popular green building certification programs used worldwide. Developed by the non-profit U.S. Green Building Council (USGBC), it includes a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighbourhoods.

6 Comprehensive Assessment System for Built Environment Efficiency (CASBEE) is a method for evaluating and rating the environmental performance of buildings and the built environment.

7 Green Globes is an online green building rating and certification tool that is used primarily in Canada and the United States. Green Globes was developed by ECD Energy and Environment Canada, an arms-length division of JLL. Green Globes is licensed for use by BOMA Canada

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1443 (Existing Buildings) and the Green Building Initiative in the United States
1444 (New and Existing Buildings).
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1446 **8** Green Star is a voluntary sustainability rating system for buildings in
1447 Australia. The Green Star rating system assesses the sustainability of
1448 projects at all stages of the built-environment life cycle. Ratings can be
1449 achieved at the planning phase for communities, during the design,
1450 construction, or fit-out phase of buildings, or during the ongoing
1451 operational phase.
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